

Enhanced Lines of Iron in the Region F to C. By A. Fowler.

In view of the now generally recognised importance of enhanced lines in the interpretation of solar and stellar spectra, it is thought that the accompanying observations of the enhanced lines of iron which occur in the less refrangible parts of the spectrum may be useful to other workers.

The lines have been observed and photographed under various conditions: in the spark, in the arc at reduced pressure, in the arc in hydrogen, and on the positive pole of an ordinary continuous-current arc in air at atmospheric pressure, metallic electrodes being used throughout. There is a distinct gain in producing the lines without the use of a spark in a few cases, inasmuch as there is no air spectrum to interfere with their detection.

The occurrence of the enhanced lines on the positive pole of the arc affords a particularly convenient mode of identifying them, except towards the red, where the continuous spectrum tends to mask the fainter lines. When the bright spot on the positive pole is carefully adjusted on the slit, the lines in question are observed as very short lines, quite different in appearance from the arc lines, which are also present and provide a convenient reference spectrum; unlike the enhanced lines, the arc lines are either weakened or unchanged on the positive pole. A similar appearance is observed on the negative pole, but the enhanced lines are not so bright. In these experiments the current has ranged from 12 to 0.4 ampères, on 110-volt circuit, with an approximately constant potential difference of 40 volts between the electrodes, and the intensities of the enhanced lines have not been found to be materially changed as compared with the arc lines observed at the same time. Even with 0.4 ampères, the arc burning continuously, all the arc lines remained visible when the proper part of the image was brought on the slit, and the enhanced lines were still very distinct in the immediate neighbourhood of the poles.

This result is somewhat different from that obtained by Hartmann with magnesium poles, in which case the enhanced line 4481 is greatly strengthened as the current is reduced. It differs also from Prof. Hale's recent observations of the iron spectrum,* in which a 2-ampère arc was found to give a spectrum closely approximating to that of the outer flame of an ordinary arc with greater current, though no material change was observed in passing from 30 to 15 ampères. It may be that the difference is partly due to the use of metallic electrodes in my experiments, while Prof. Hale appears to have used the metal on carbon poles; under the latter conditions I have obtained similar results with the 2-ampère arc, but only when the quantity of iron on the poles was small. At all events, when metallic poles are used, reduction of current strength does not appear to be accompanied by a reduction of temperature sufficient to produce any notable differences in the

* *Astrophys. Journal*, vol. xxiv. p. 208.

spectrum, if corresponding parts of the arc be observed in each case. Indeed, this observation accords well with Prof. J. J. Thomson's remark* that in the arc "the temperature of the crater of the positive terminal remains constant even when the current varies."

It should be remarked, however, that the similarity of the phenomena in the 2-ampère iron arc with those observed when the current strength is greater does not in the least invalidate Prof. Hale's conclusion as to the probable low temperature of sun-spots. As in my own discussion of this point,† Prof. Hale's result ultimately depends upon a comparison of spot spectra with the spectrum of the arc-flame.

The wave-lengths of all the lines given in the table have been determined from a new series of photographs in which the linear dispersion from C to F is 24 cm. The results have differed so slightly (rarely more than 0.02) from solar lines of appropriate intensity tabulated by Rowland that there can be no doubt as to their identity, and to avoid any possible confusion, Rowland's wave-lengths have been adopted. This procedure is, in fact, justified by Lockyer and Baxandall's demonstration ‡ of the presence of enhanced lines of iron in the more refrangible parts of the solar spectrum.

The representation of the additional lines with proper intensities in the Fraunhofer spectrum, together with their special behaviour in the chromosphere and spots, § is valuable confirmation of their classification as enhanced lines. A few lines, notably two at wavelengths 5260.50 and 5100.95 which appear in some of the spectra, have not been included in the table because they failed to satisfy these conditions, although the probable impurity producing them has not yet been traced. That such lines were due to some substance other than iron was further suggested by their variable intensities with respect to undoubted enhanced lines. Prof. Hale has met with a somewhat similar case in a supposed enhanced line of iron at 5218.37, of which he says that "the enhancement of this line may vary." Here, however, there can be no hesitation in attributing the line to copper, which is a very common impurity in iron.

There is, in fact, no reason to suppose that the intensities of the enhanced lines are appreciably different relatively to each other under any of the conditions of experiment which have been mentioned, though their intensities, as compared with the arc lines, are not the same in all cases. The enhancement is most marked in the spark spectrum. Estimates of the relative intensities are given in the table.

For the sake of completeness, the table also shows the behaviour of the lines in the chromosphere and sunspots, Y, H, M, and F respectively indicating Young, Hale, Mitchell, and Fowler.

* *Discharge of Electricity through Gases* (1903), p. 417.

† *Trans. Int. Solar Union*, vol. i. p. 228 (1906).

‡ *Roy. Soc. Proc.*, vol. lxxiv. p. 225 (1904).

§ *Monthly Notices*, vol. lxvi. p. 361 (1906).

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Enhanced Fe.	⊙ Rowland.	Wavelength.	Int.	Origin.	Int.	Behaviour in Sun-Spots.	Intensity in Chromosphere.			Remarks.
							Y	M	F	
4924·11*	9	Fe	5	Weakened	H, F	10	15	25		
5018·63*	9	Fe	4	,,	H, F	15	10	25		
5169·22*	10	Fe	4	,,	H, M, F	25	25	40		
5197·74†	4	...	2	,,	H, M, F	10	15	25		
5234·79†	4	...	2	,,	H, M, F	10	15	25		
5264·98	1	...	0	,,	H, F	3	7	15		
5276·17*	6	Fe?	3	Not clearly affected	M, F	10	8	35	Compound line in ⊙, 76·24, 76·17.	
5316·79*	9	Fe	4	Weakened	Y, H, F	2-20	20	45		
5325·74	2	...	(2)	,,	Y, F	2	10	15	Rowland's ⊙ int. too high.	
5363·06†	5	...	3	,,	F	5-10	8	30		
5535·06†	4	Fe	2	,,	H, M, F	12	12	35	Masked by air line in spark.	
6238·50	3	...	2	,,	M, F	2	...	15		
6247·77	3	...	2	,,	M, F	4	...	20	Observed also in spark by Mitchell.	
6417·13	2	Fe?	1	,,	M, F	2		
6456·60†	6	...	3	,,	M, F	3-10	5	20		

It will be seen that the representation of the enhanced lines in the solar spectrum, and in the spectrum of the chromosphere and sun-spots, is quite consistent throughout. As in the case of Lockyer and Baxandall's investigation of the more refrangible parts of the spectrum, origins are now provided for several lines unidentified or doubtfully identified by Rowland, the reason being that he did not ordinarily obtain the weaker enhanced lines in his photographs, and probably attributed their occasional appearance to impurities.

There is abundant evidence that all the enhanced lines of iron in the region F to C are weakened in the spectra of sun-spots, and the work at Mount Wilson has already shown that the same is true of many of the lines of this class in the blue and violet.

All the lines in question are also prominent in the spectrum of the chromosphere, and, according to my previous observations, are of the high-level type, with the possible exception of 6417·7, which is not yet included in my list, but is given by Young.

It is sufficiently clear, therefore, that the enhanced lines constitute a special system of lines which vary together both in laboratory experiments and in the various parts of the sun where they are observed.

Note.—It may be mentioned that, while generally confirming Lockyer's list of enhanced lines of iron in the more refrangible parts of the spectrum, the special photographs of the arc reveal an additional line of considerable intensity at 4416·98, which is masked by an air line in the spark. This line also is weakened in the sun-spot spectrum.

* Previously recorded by Lockyer, *Pub. Sol. Phys. Obs.*, 1906, etc.

† ,,, ,,, Author, *Monthly Notices*, vol. lxvi. p. 364, 1906.

Note on Silicon in the Chromosphere. By A. Fowler.

Pending a more complete investigation of the spectrum of silicon in relation to the chromosphere and Sun-spots, it may be of interest to draw attention to the identification of two strong red lines of this element with well-marked chromospheric lines. The lines in question have been previously observed in the spark spectrum by Salet ($\lambda\lambda$ 6341, 6366), by the Count de Gramont ($\lambda\lambda$ 6342, 6370), and more recently by Lunt, who gives the approximate wave-lengths 6346·9 and 6371·2.*

A careful re-determination of the positions of these lines, from photographs giving a linear dispersion of 10 tenth-metres to the millimetre in this part of the spectrum, leaves no doubt as to their coincidence with the previously unidentified high-level chromospheric lines at 6347·31 and 6371·57. The more refrangible of the two lines is the stronger, in the proportion of about 10 to 6, and their intensities in the chromosphere, according to my own observations,† are 25 and 15 respectively. Both lines occur in the Fraunhofer spectrum, with intensities and characters 2N and 1Nd? respectively, and Rowland assigns the latter to iron, while leaving the other unidentified. Kayser and Runge also give a faint line at 6371·60 in the arc spectrum of iron, but it does not appear on my photographs of the iron spectrum, except when the presence of silicon is indicated by the other line at 6347·31. In any case, if there be an iron line at 6371·57, it is not an enhanced line, and is not of sufficient intensity in the arc to account entirely either for the Fraunhofer or chromospheric line at the same wave-length, which must accordingly be attributed chiefly to silicon.

In Sun-spots, according to the observations of Mitchell‡ and myself, the two lines are almost obliterated, so that there is a complete agreement of behaviour and intensities throughout.

The relationships of the different families of silicon lines have not yet been fully worked out, but it is probable that the two red lines, like so many of the other high-level chromospheric lines which are weakened in spots, belong to the enhanced line class. Like the enhanced lines of iron, they appear close to the positive pole when a little silica is introduced into the iron arc, and the wave-lengths have been determined by reference to adjacent iron lines which occur with the silicon lines under these conditions. In his recent discussion of the violet part of the flash spectrum Prof. Dyson§ concluded that there was "a fair degree of probability for the existence of silicon in the chromosphere," and all doubt is now removed by the identification of the red lines.

* *Annals of the Cape Observatory*, vol. x., Part II., p. 18B (1906).

† *Monthly Notices*, vol. lxvi. p. 365 (1906).

‡ *Astrophys. Jour.*, vol. xxiv. p. 92 (1906).

§ *Phil. Trans.*, vol. ccvi. A, p. 440 (1906).